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EVALUATION OF KINERGETICS BREATHING GAS HEATER.(U)
APR 78 J R MIDDLETON, B E MILLER
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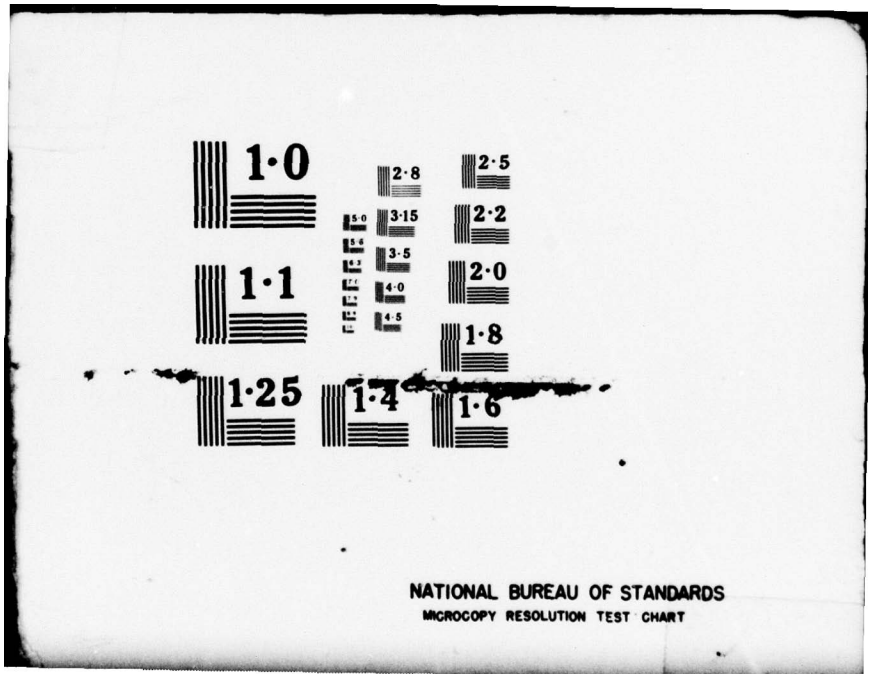
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(6) EVALUATION OF KINERGETICS BREATHING GAS HEATER.

(10) JAMES R./MIDDLETON
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Pressure drop	Diver work rate	
Breathing resistance	Watts	
Hot water flow rate	Gas heater	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Kinergetics Breathing Gas Heater Model 3375-2 was tested by NEDU and NCSC in conjunction with the USN MK 1 Mod S mask during a 1500 fsw saturation dive in December 1977. Data was gathered at depths ranging from 1120 to 1250 fsw on divers performing light to extreme work on a bicycle ergometer.

The heater produced extremely low pressure drops in the gas flow path and did not interfere with the breathing characteristics of the

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mask. The heater is simple to use and does not substantially complicate the use of the MK 1 Mod S mask.

Results showed that the heater can effectively raise diver breathing gas temperature from an inlet value of 50°F to an outlet value of 100°F when operating according to manufacturer's specifications. However, as the warm gas flows from the heater through the mask sideblock and demand regulator into the oral-nasal cup, it will cool to approximately 75°F (in 40°F ambient H_2O). Consequently, to realize full heater potential some form of mask sideblock heating should be incorporated into the system.

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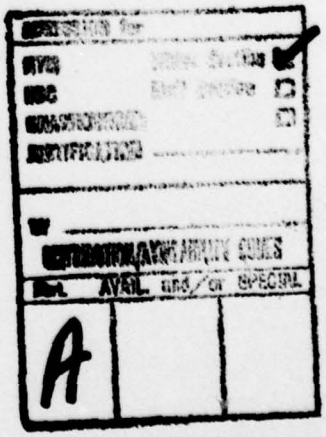

Glossary

Abbreviation	Definition
ACFM	Actual Cubic Feet per Minute
cm H_2O	Centimeters of Water Pressure (differential)
°F	Degrees Farenheit
fsw	Feet of Seawater
GPM	Gallon Per Minute Water Flow Rate
HeO_2	Helium-Oxygen Breathing Gas
I.D.	Inside Diameter
NCSC	Naval Coastal Systems Center
NEDU	Navy Experimental Diving Unit
NPT	National Pipe Thread
O/B	Over Bottom Pressure
O.D.	Outside Diameter
psig	Pounds Per Square Inch Gauge

Abstract

The Kinergetics Breathing Gas Heater Model 3375-2 was tested by NEDU and NCSC in conjunction with the USN MK 1 Mod S mask during a 1500 fsw saturation dive in December 1977. Data was gathered at depths ranging from 1120 to 1250 fsw on divers performing light to extreme work on a bicycle ergometer.

The heater produced extremely low pressure drops in the gas flow path and did not interfere with the breathing characteristics of the mask. The heater is simple to use and does not substantially complicate the use of the MK 1 Mod S mask.

Results showed that the heater can effectively raise diver breathing gas temperature from an inlet value of 50°F to an outlet value of 100°F when operating according to manufacturer's specifications. However, as the warm gas flows from the heater through the mask sideblock and demand regulator into the oral-nasal cup, it will cool to approximately 75°F (in 40°F ambient H_2O). Consequently, to realize full heater potential some form of mask sideblock heating should be incorporated into the system.

I. INTRODUCTION

In December 1977 during Deep Dive 77, NEDU tested a breathing gas heater produced by Kinergetics Incorporated, 6029 Reseda Boulevard, Tarzana, California 91356. Kinergetics produces several breathing gas heaters which are currently under consideration for use by the U.S. Navy. Each heater has a slightly different physical configuration although performance specifications are identical. Model 3375-2 was selected for these tests as the most likely to meet Navy saturation diving requirements.

No data existed on this heater's actual performance characteristics during manned diving operations. Consequently, the objective of these tests was as follows:

A. To determine if the Kinergetics Breathing Gas Heater meets manufacturer's design performance specifications.

B. To determine if the Kinergetics Breathing Gas Heater is a practical device for supplying a working diver with warm breathing gas when used in conjunction with the USN MK 1 Mod S mask.

C. To determine if breathing resistance in the MK 1 Mod S mask is substantially increased when used in conjunction with Kinergetics Breathing Gas Heater.

The heater was tested by six divers at depths ranging between 1120 and 1250 fsw at light to extreme work rates on a bicycle ergometer. Gas and water temperatures, breathing resistance and pressure drops across the heater were monitored.

An unmanned evaluation of the Kinergetic heaters was conducted by Barry Miller of NCSC in reference 1 which provides comparative data further verifying the results of this test series.

II. TEST PROCEDURE

A. Test Plan

The Kinergetics Heater was instrumented and mounted on the diver as shown in Figure 1. Three divers were used for the test with each diver making two dives in the equipment. Each diver was dressed in a MK 1 Mod S mask, Model 3375-2 Kinergetics Breathing Gas Heater and hot water suit. The heater was mounted on a single scuba tank back pack which was worn over the hot water suit. A scuba tank was not attached to the back pack for these tests. All instrumentation leads were run through a tygon tube attached to the divers umbilical into a computer

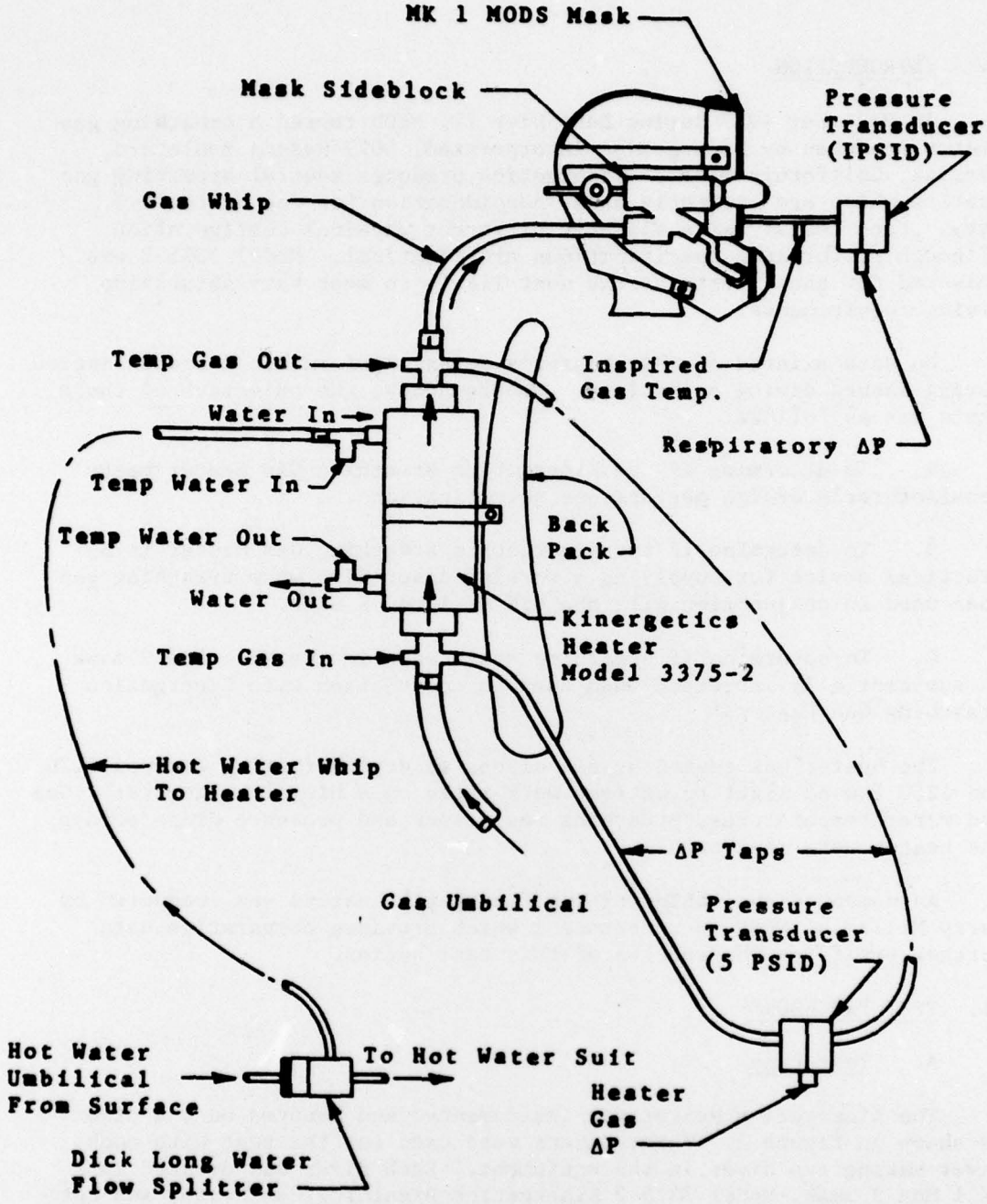

FIGURE 1 KINERGETICS TEST SET UP

for data acquisition. Data was taken on each diver as he performed light to extreme exercise on a calibrated bicycle ergometer. The divers performed the heater evaluation during two dive days in 40°F water as the chambers were being decompressed from 1500 fsw with the actual test depths varying between 1250 to 1120 fsw. At the conclusion of the first day of tests, the hot water flow rate to the suit and heater was reduced from 5 to 4 GPM because the suits ballooned on the divers at the higher flow rate. Input water temperature was subsequently increased from 112 to 115°F at the control manifold to the hot water umbilical to compensate for the reduced flow. A T-splitter was used at the suit manifold to divert a portion of the umbilical water flow to the heater.

A heat exchanger was used to cool the divers breathing gas temperature to approximately 50°F before it entered the heater.

The instrumentation and test equipment shown in Figure 1 is listed in Appendix A. Parameters controlled and measured are listed below.

B. Controlled Parameters

1. Hot water umbilical water flow rate:

   Test #1: 5 GPM
   Test #2: 4 GPM

2. Water flow rate to hot water suit:

   Test #1: 4 GPM
   Test #2: 3.25 GPM

3. Water flow rate through heater:

   Test #1: 1 GPM
   Test #2: 0.75 GPM

4. Water temperature into heater:

   Test #1: 110°F
   Test #2: 115°F

5. Test depth: 1120-1250 fsw

6. Diver work rate: 25-150 watts in 25 watt increments. Each diver started work at 25 watts for 6 minutes, rested 4 minutes, then increased his work rate by 25 watts for another 6 minute work period, etc.

7. Wet chamber water temperature: 40°F

8. Breathing gas temperature into heater: 50°F

9. Diver breathing gas umbilical length: 200 ft.

10. Breathing gas umbilical supply pressure: 180 psig O/B

11. Hot water umbilical length: 50 ft.

12. Diver breathing gas mix: HeO_2

C. Measured Parameters

1. Water temperature into heater (°F)

2. Water temperature out of heater (°F)

3. Gas temperature into heater (°F)

4. Gas temperature out of heater (°F)

5. Diver inspired gas temperature (°F)

6. MK 1 Mod S mask breathing resistance (cmH_2O)

7. Water flow rate through hot water umbilical (GPM)

8. Gas pressure drop across Kinergetics Heater (psig)

III. RESULTS AND DISCUSSION

A. Description

The Kinergetics Breathing Gas Heater is a small cylinder (2.25 inch O.D. x 8.00 inch long) weighing approximately 3 pounds. The external shell is stainless steel with the heat exchanger core being nickel plated copper. It is designed to operate with 1 GPM flow rate at an inlet temperature of 110°F. The unit is a counter flow heat exchanger which mounts on the side of the bailout bottle used with the MK 1 Mod S mask. It is in series with the gas flow path and all breathing gas passes through it before reaching the mask.

The heater is designed to be used with HeO_2 gas mixes and the factory performance specifications are as follows: (Model 3375-2)

1. Gas flow rate: 1.5 ACFM average with peak flows of 20 ACFM

2. Gas outlet temperature: 94°F or greater with an inlet gas temperature of 35°F

3. Operating pressure: 150 psig O/B or greater

4. Gas pressure drop: less than 7 psig at 6 ACFM

5. Water flow rate: 1 GPM

6. Water inlet temperature: 110°F

7. Water pressure drop: less than 6 psig at 1 GPM flow rate

8. Gas inlet and outlet connections: 3/8" female NPT

9. Water inlet and outlet connections: 1/2" female NPT

10. Maximum operating depth: 1500 fsw

11. Type of heat exchanger: counterflow

A T-splitter was used to divert portions of the water from the hot water umbilical to the heater. The splitter was calibrated to send 4 GPM to the hot water suit and 1 GPM to the heater with an umbilical flow rate of 5 GPM. In addition, with an umbilical flow rate of 4 GPM, 3.25 GPM went to the hot water suit and 0.75 GPM went to the diver breath heater. The splitter was located at the manifold on the hot water suit, and was manufactured by Diving Unlimited, International, 1148 Delevan Drive, San Diego, California 92102.

B. Gas Heating Tests

1. Test No. 1

During the first test the divers were at depths ranging from 1250 to 1220 fsw. The hot water umbilical flow rate was maintained at 5 GPM and the water temperature at the upstream end of the hot water umbilical was held at 112°F $\pm$1°F. The breathing gas chiller unit was able to maintain the breathing gas temperature at approximately 50°F with an ambient water temperature of 40°F.

Three divers used the MK 1 Mod S mask/Kinergetics Heater at work rates varying from 25 to 150 watts measured on a Collins Vertical Ergometer. Diver work rate had no effect on heater performance nor was any change observed during rest periods.

The results of these tests are summarized in Table 1. It is important to note that the gas temperature out of the heater met manufacturers specifications with gas inlet temperatures of 50°F.

As evidenced in Table 1, the main problem encountered was the cooling of the heated gas that occurred between the heater outlet and oral-nasal cup inside the mask. Inspired gas temperatures were approximately 20°F less than the gas exiting in the heater. The largest portion of this heat loss is thought to occur in the brass mask sideblock. In order to achieve the full heating potential of the Kinergetics Heater some type of sideblock heating is required.

Only a two degree temperature loss was observed as the hot water traveled through 50 feet of hot water umbilical from the chamber manifold to the diver. This drop is not significant and will not affect heater performance.

TABLE 1

TEMPERATURES °F

Diver No.	Gas Into Heater	Gas Out Of Heater	Inspired Gas	Ambient H_2O	H_2O Into Heater	H_2O Out Of Heater	Chamber H_2O Manifold
1	50.1	96.0	77.5	40.0	110	105.0	112.0
2	48.7	96.9	74.5	40.0	110	97.8	112.0
3	48.3	95.4	74.6	40.0	110	100.0	112.0

NOTE: (1) Divers depth: 1250-1220 fsw

(2) Hot water umbilical flow rate: 5 GPM with 4 GPM to suit and 1 GPM to heater

2. Test No. 2

Test parameters were identical to dive day 1 except that hot water umbilical flow rate was reduced to 4 GPM. Hot water suit ballooning was experienced during the previous day due to the high flow rates and the reduced flow corrected the problem. In addition, since less umbilical flow also reduced hot water flow to the heater from 1.0 to 0.75 GPM, the chamber manifold temperature was increased from 110 to 115°F to maintain heater efficiency.

The results are summarized in Table 2. As seen from the data, the increased water temperature to the heater more than offsets any losses due to reduced flow rates. Gas exited the heater at 104°F. This is almost 10 degrees higher than Test #1. However, inspired gas temperatures were comparable to the first test and further verify the need for mask sideblock heating.

TABLE 2

TEMPERATURES °F

Diver No.	Gas Into Heater	Gas Out Of Heater	Inspired Gas	Ambient H_2O	H_2O Into Heater	H_2O Out Of Heater	Chamber H_2O Manifold
1	49.6	104	76.7	40.0	115	108	115
2	51.8	101	76.0	40.0	115	106	115
3	49.1	104	77.3	40.0	114	106	115

NOTE: (1) Divers depth: 1150-1120 fsw

(2) Hot water umbilical flow rate: 4 GPM with 3.25 GPM to suit and 0.75 GPM to heater

C. Breathing Resistance Tests

Inhalation resistance was monitored throughout the tests via the pressure transducer located on the mask. It measured inhalation and exhalation pressure in the oral-nasal cavity relative to the ambient pressure.

Breathing resistance varied from 5 to 30 cmH_2O on inhalation as the divers work rate increased from 25 to 150 watts on the bicycle ergometer. These values are identical to those measured on previous dives using the MK 1 Mod S mask without a breathing gas heater. Consequently, no additional breathing resistance is incurred by adding the Model 3375-2 heater to the life support system.

D. Kinergetics Heater Pressure Drop Tests

A 5 psi differential pressure transducer was mounted across the gas inlet and outlet ports on the heater. This was done to determine if excessive pressure losses in the heater would result in increased diver breathing resistance.

A maximum pressure loss of 0.5 psig occurred at 150 watts at 1250 fsw. This is extremely low and had no effect on mask breathing resistance.

IV. CONCLUSIONS AND RECOMMENDATIONS

The Kinergetics Heater Model 3375-2 was found to be an effective means of heating diver breathing gas in the saturation mode. It can be simply adapted for use with the MK 1 Mod S mask and hot water suit. Due to its low pressure drop characteristics, no degradation in MK 1 Mod S mask performance was observed when using the heater.

The full potential of the heater cannot be realized without mask sideblock heating. While a 20°F temperature increase over heater inlet gas was measured at the oral-nasal cup, this is insufficient as an effective means of diver heating. Kinergetics Incorporated has indicated it has the capability to modify this heater to direct the hot water exhausted from the unit up to the mask sideblock which, if combined with a jacket around the sideblock to direct the hot water flow, should solve the system inadequacies identified during these tests. It is planned that further investigation of the Kinergetics heater be conducted on the next NEDU saturation dive with the above modifications incorporated into the system.

V. REFERENCES

1. Breathing Gas Heater Test Results, October 1977, Technical Memorandum NCSL-206-77, B. E. Miller

APPENDIX A

Test Equipment

(Note: Equipment numbers correspond to those in Figure 1)

1. Validyne 1 psid pressure transducer (1 ea)
2. Validyne 5 psid pressure transducer (1 ea)
3. Validyne CD-19 transducer readouts (2 ea)
4. Thermisters (5 ea)
5. Thermister readouts (5 ea)
6. Rotometer (1 ea)
7. MK 1 Mod S mask (1 ea)
8. Kinergetics heater model 3375-2 (1 ea)
9. Hot water wet suits
10. Scuba tank back pack (1 ea)
11. Collins Vertical bicycle ergometer (1 ea)
12. Wet pot gas chiller unit
13. 8 channel strip chart recorder
14. 200 ft. gas supply umbilical
15. 50 ft. hot water umbilical
16. OSF computer data acquisition system